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THE APPLICABILITY OF SPECIAL SUBJECT GROUPS FOR ASSESSING PASSENGER REACTION TO FLIGHT ENVIRONMENTS

STOL Program Memorandum Report 403211

by

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Introduction

In determining a model for predicting the comfort level of passengers on commercial aircraft it is sufficient to be able to assess his or her overall reaction to the flight environment. The data needed for the model can be obtained by direct assessment of passenger reaction and correlation of these responses with the flight environment. This approach has two major drawbacks: a) it is an expensive procedure, if the model is to include all combinations of flight environment which can be encountered; and, b) many flight environments of interest for future systems are not encountered at all. The passengers, however, are the group for which a model is required; therefore, some means to obtain the desired results must be found. There are two methods for obtaining the information: a) finding a special test group of subjects whose responses correlate with those of passengers; and b) reliance on experienced crew and flight attendants to assess the comfort of their passengers. Either of these groups could then be used in an extensive flight and ground simulation program to assess those aspects of the flight environment which cause discomfort. One of the areas to be considered in this report is an assessment of the degree to which a special subject group or crew/flight attendants are a true representation of the passengers.

A second factor which must be considered is the effect of time sequence on overall response. The designer needs some method by which he can take a time history of an aircraft's flight environment and determine what the overall passenger response will be. A means of predicting the manner in which information is processed (integrated) throughout a flight to arrive at an overall comfort response is presented.

Data Acquisition

The data was obtained on regularly scheduled commercial airline flights (Allegheny Airlines). On each flight where questionnaires (Figure 1) were distributed to the passengers (which they completed just prior to landing), a questionnaire (Figure 2) was given to each crew/flight attendant and to each of one or two special subjects (Figure 3). In addition, the special subjects gave running indications (every 2 - 4 minutes) of their level of comfort during the flight. Data was obtained on three aircraft, the Twin Otter, Volpar Beach 18, and NORD 262.

Passenger/Crew Responses

The relationship between the responses of the crew and those of the passengers can be seen in Figures 4 and 5. Figure 4 shows that over all flights the crew (including flight attendants) are essentially insensitive to the motion environment (rarely uncomfortable). This is further seen by comparison of the overall means:

Crew Mean = 1.72

Passenger Mean = 2.65

It is important to note that the crew is being asked to assess their passengers comfort level, not their own, and on an average consider their passengers to be between very comfortable and comfortable.

Figure 5 is a scattergram of crew versus passenger mean response for each flight. As can be seen, there is no discernible relationship between the two with only 25% falling within $\pm.5$ of the P=C (Passenger = Crew) response line.[1]

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[1] Since the data is integer valued, round-off will result in a zero average error if the error is randomly distributed.

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ALLEGHENY COMMUTER
Operated by Atlantic City Airlines, Inc.

UNIVERSITY OF VIRGINIA

This questionnaire is part of an effort by Atlantic City Airlines, the National Aeronautics and Space Administration, and the University of Virginia to obtain from you, the flying public, information to be used in the improvement of transportation systems. The goal of the program is to identify the needs and desires of airline passengers, so that future systems may increase passenger satisfaction.

Your cooperation in completing this form will be most appreciated and can only be of benefit to you, the air traveler. Thank you, and enjoy your flight.

Maurice C. Young
President, Atlantic City Airlines, Inc.

Please indicate only your first impression on each question. You need not answer any question that offends you.

1. Age _____ 2. Sex: ☐ M ☐ F

3. Education:
   - ☐ High School not completed
   - ☐ High School completed
   - ☐ College

4. Occupation:
   - ☐ Housewife
   - ☐ Craftsman, Mechanic
   - ☐ Professional, technical
   - ☐ Professional, nontechnical
   - ☐ Student
   - ☐ Armed Forces
   - ☐ Secretary, Clerk
   - ☐ Salesman
   - ☐ Manager, Official, Executive
   - ☐ Other _____

5. Industry of Employment _____

6. Approximate Household Income (before taxes):
   - ☐ Under $5,000
   - ☐ $ 5,000-$ 9,999
   - ☐ $10,000-$14,999
   - ☐ $15,000-$19,999
   - ☐ $20,000-$24,999
   - ☐ $25,000-$29,999
   - ☐ $30,000-$34,999
   - ☐ $35,000 or more

7. What is the primary purpose of this trip?
   ☐ Business ☐ Personal ☐ Other

8. How do you feel about flying?
   - ☐ I love flying
   - ☐ I have no strong feelings about flying
   - ☐ I dislike flying
   - ☐ I fly because I have to

9. Approximately how many times have you flown in the past **two** years?
   - ☐ None, this is my first flight
   - ☐ 1-3
   - ☐ 4-6
   - ☐ 7-9
   - ☐ 10 or more

10. How important is each of the following items in determining your feelings of comfort? Rank them using the numbers from 1 to 9, with 1 representing the **most important**, and 9 the least important. Please use each number only once.
    - _____Pressure changes (ears pop)
    - _____Noise
    - _____Temperature
    - _____Lighting
    - _____Seat comfort
    - _____Up and down motion (bouncing)
    - _____Side to side motion (rolling)
    - _____Work space and facilities
    - _____Presence of smoke

    Other _____

11. Place a check in the box which describes the importance of each of the following in determining your satisfaction with an airplane ride.

	Unimportant	Very Little Importance	Somewhat Important	Very Important	Greatest Importance
Comfort	☐	☐	☐	☐	☐
Convenience	☐	☐	☐	☐	☐
Cost	☐	☐	☐	☐	☐
Reliability	☐	☐	☐	☐	☐
Safety	☐	☐	☐	☐	☐
Time Savings	☐	☐	☐	☐	☐
Ability to Read	☐	☐	☐	☐	☐
Ability to Write	☐	☐	☐	☐	☐
Services on Board	☐	☐	☐	☐	☐
Surroundings	☐	☐	☐	☐	☐

12. Consider the motion you are experiencing. Indicate your reaction to this motion by checking the appropriate box:
    - ☐ Very Comfortable
    - ☐ Comfortable
    - ☐ Neutral
    - ☐ Uncomfortable
    - ☐ Very Uncomfortable

13. How difficult does the motion of this flight make the following activities?

	Not at all Difficult	Slightly Difficult	Difficult	Extremely Difficult	Impossible
Concentration	☐	☐	☐	☐	☐
Reading	☐	☐	☐	☐	☐
Writing	☐	☐	☐	☐	☐
Sleeping	☐	☐	☐	☐	☐

14. After experiencing the motion of this flight, I would: (Check only one)
    - ☐ be eager to take another flight
    - ☐ take another flight (without any doubts)
    - ☐ take another flight (but with some doubts)
    - ☐ prefer not to take another flight
    - ☐ not take another flight

15. Suppose a high-frequency shuttle service (8 or more round trips per day) were available at your local airport, scheduled to connect with flights of over 300 miles from a larger airport some distance away. Would you use the shuttle instead of ground transportation to the larger airport, if the cost were competitive?
    ☐ Yes ☐ No

16. Suppose a 25-passenger prop jet flew from an airport 15 minutes from your home or office to cities within 300 miles. Would you use this service rather than travel to a major airport an hour away?
    ☐ Yes ☐ No

(Please see last page)

THANK YOU FOR YOUR ASSISTANCE

FIGURE 1. PASSENGER QUESTIONNAIRE

ALLEGHENY COMMUTER

UNIVERSITY OF VIRGINIA

Ten minutes before the end of this flight, please answer the following two questions without consulting other members of the flight crew. Your answers are confidential.

FLIGHT CREW QUESTIONNAIRE

Date Flight #

Origin Destination

Pilot [ ] First Officer [ ] Stewardess [ ]

Takeoff Gross Weight_____ lbs.

Cruise: Altitude_____ ft.

Air Speed_____knots Ground Speed_____

Ambient Temp._____ F.

Winds: _____

[ ] VFR [ ] IFR

Unusual Occurrences?

Comments:

How comfortable do you think the motion of this flight made your passengers?

[ ] Very Comfortable

[ ] Comfortable

[ ] Neutral

[ ] Uncomfortable

[ ] Very Uncomfortable

How difficult did the motion of this flight make the following activities for the passengers?

	Not at all Difficult	Slightly Difficult	Difficult	Extremely Difficult	Impossible
Concentration	[ ]	[ ]	[ ]	[ ]	[ ]
Reading	[ ]	[ ]	[ ]	[ ]	[ ]
Writing	[ ]	[ ]	[ ]	[ ]	[ ]
Sleeping	[ ]	[ ]	[ ]	[ ]	[ ]

FIGURE 2. CREW QUESTIONNAIRE

1. Indicate your overall reaction to the motion environment you experienced on this flight.

( ) Very Comfortable

( ) Comfortable

( ) Neutral

( ) Uncomfortable

( ) Very Uncomfortable

2. How difficult did the motion of this flight make the following activities?

	Not at all Difficult	Slightly Difficult	Difficult	Extremely Difficult	Impossible
Concentration	( )	( )	( )	( )	( )
Reading	( )	( )	( )	( )	( )
Writing	( )	( )	( )	( )	( )
Sleeping	( )	( )	( )	( )	( )

FIGURE 3. SUBJECT QUESTIONNAIRE

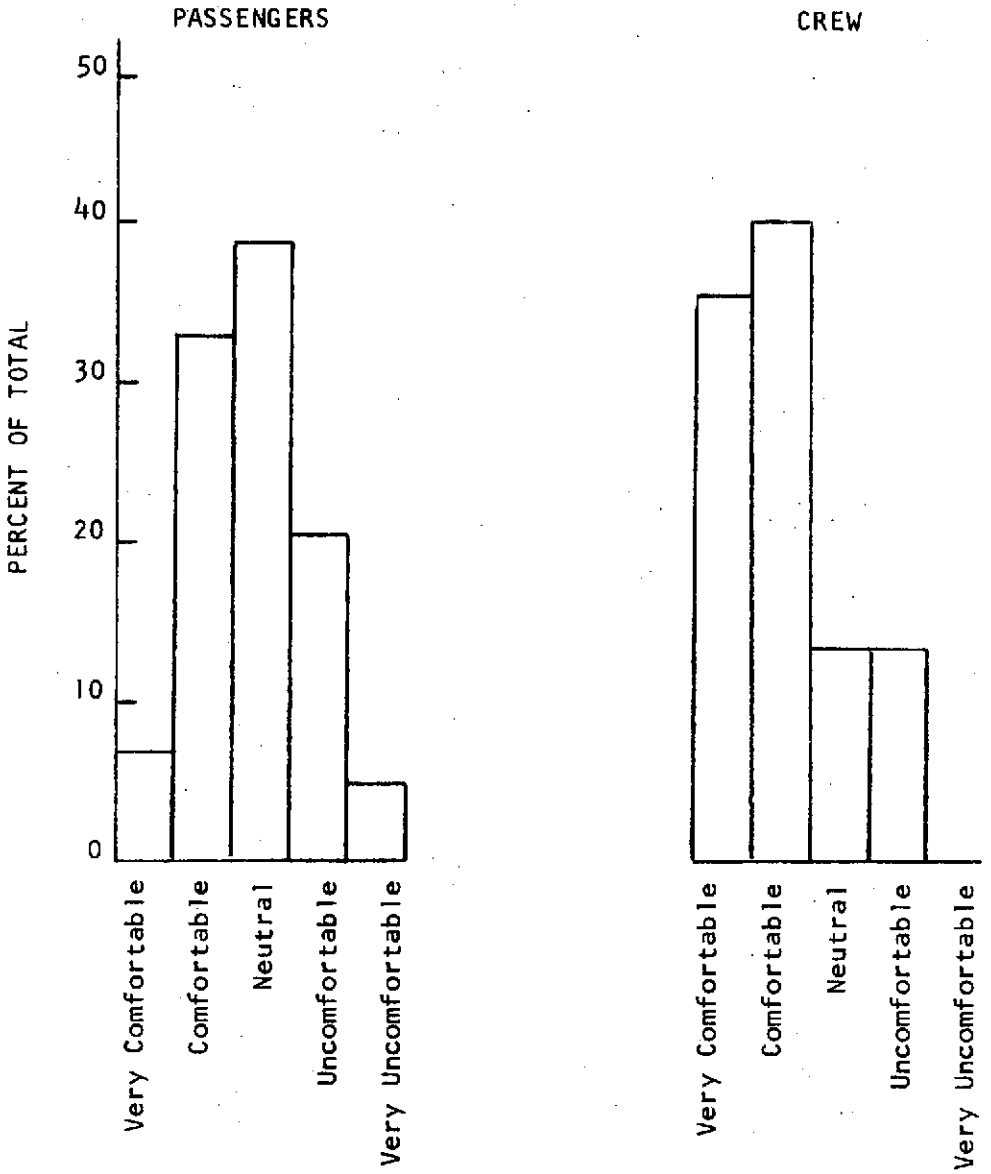


FIGURE 4. PASSENGER/CREW EVALUATIONS--OVERALL COMFORT
(All Aircraft; All Passenger Types)

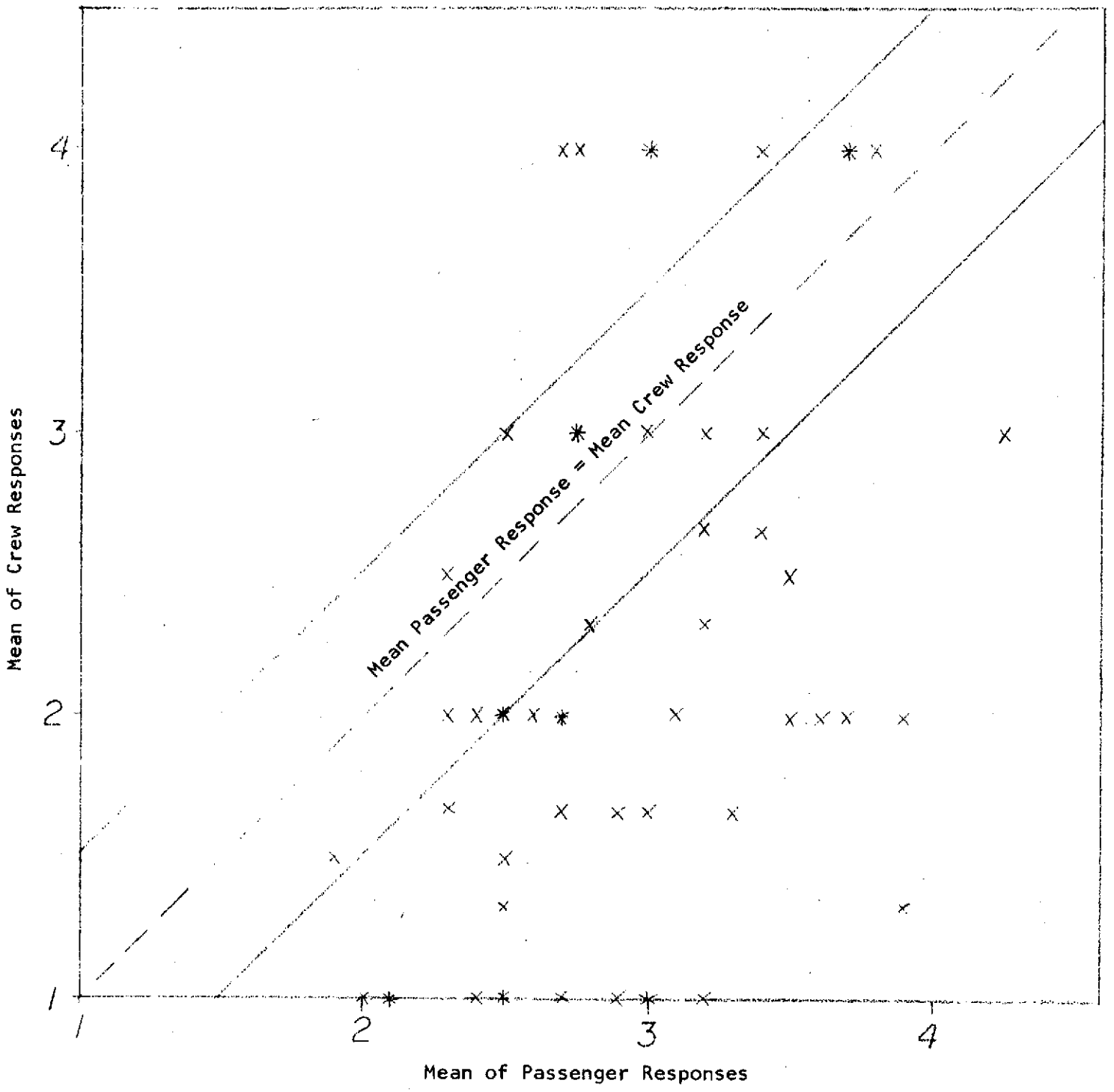


FIGURE 5. COMPARISON OF PASSENGER/CREW RESPONSES

Possible causes for these discrepancies are: a) the crew/flight attendants are busy with tasks during flight and cannot easily assess the ride; and b) the crew members are more attuned to handling qualities and this perhaps alters their opinions on ride qualities. The results, however, indicate unmistakably that the crew is a poor indicator of passenger comfort.

Passenger/Subject Responses

Figure 6 illustrates the agreement over all flights between subjects and passengers. It can be seen that the distributions are similar except that the subjects do not respond at the one level (very comfortable). Figure 7 shows a comparison of subject overall responses versus the mean of passenger responses on a flight-by-flight basis. There appears to be poor agreement (about 40% outside the $\pm.5$ bound) between the two. Hence a one-to-one linear relationship between the two does not exist. The question arises, then, as to whether the passengers and subjects agree (in some sense of the word) at all.

On an average, there are 10 passengers per flight. Typical scatter among their responses is shown in Figure 8. As is seen, when the mean of responses falls clearly into either the comfortable or uncomfortable range (8a., 8c.), there is general agreement among the passengers; however, when the mean is in the vicinity of the neutral point (8b.), considerable disparity in feelings is seen. The majority of data obtained to date have means on the comfortable side of neutral (i.e., $\bar{C} < 3.0$). This implies that most passengers are not uncomfortable. Typically 10 - 20% of passengers were either uncomfortable or very uncomfortable when the majority were not. Overall, the subjects agree with the majority of passengers (25 of 27 cases).

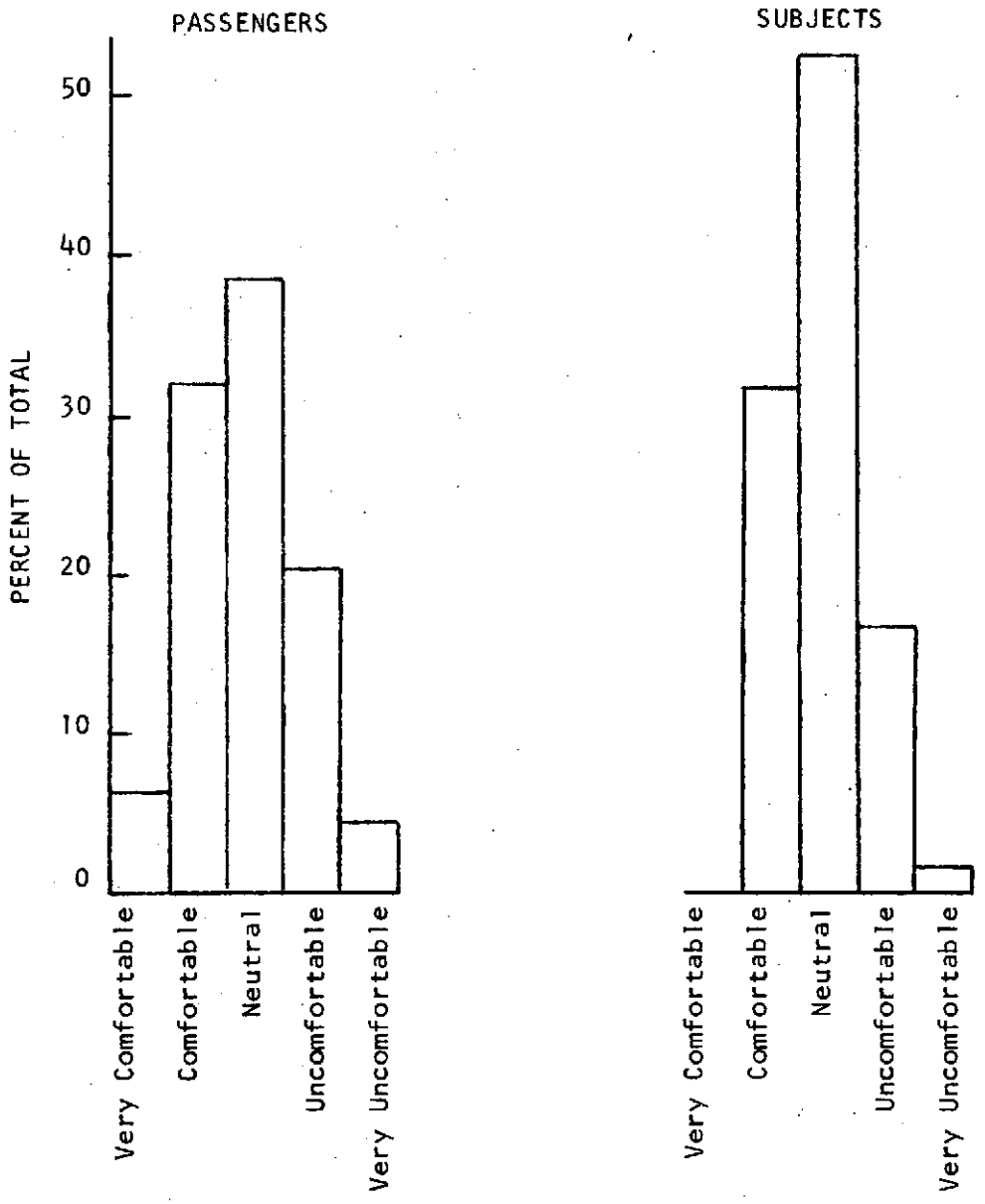


FIGURE 6. PASSENGER/SUBJECT EVALUATIONS--OVERALL COMFORT
(All Aircraft; All Passenger Types)

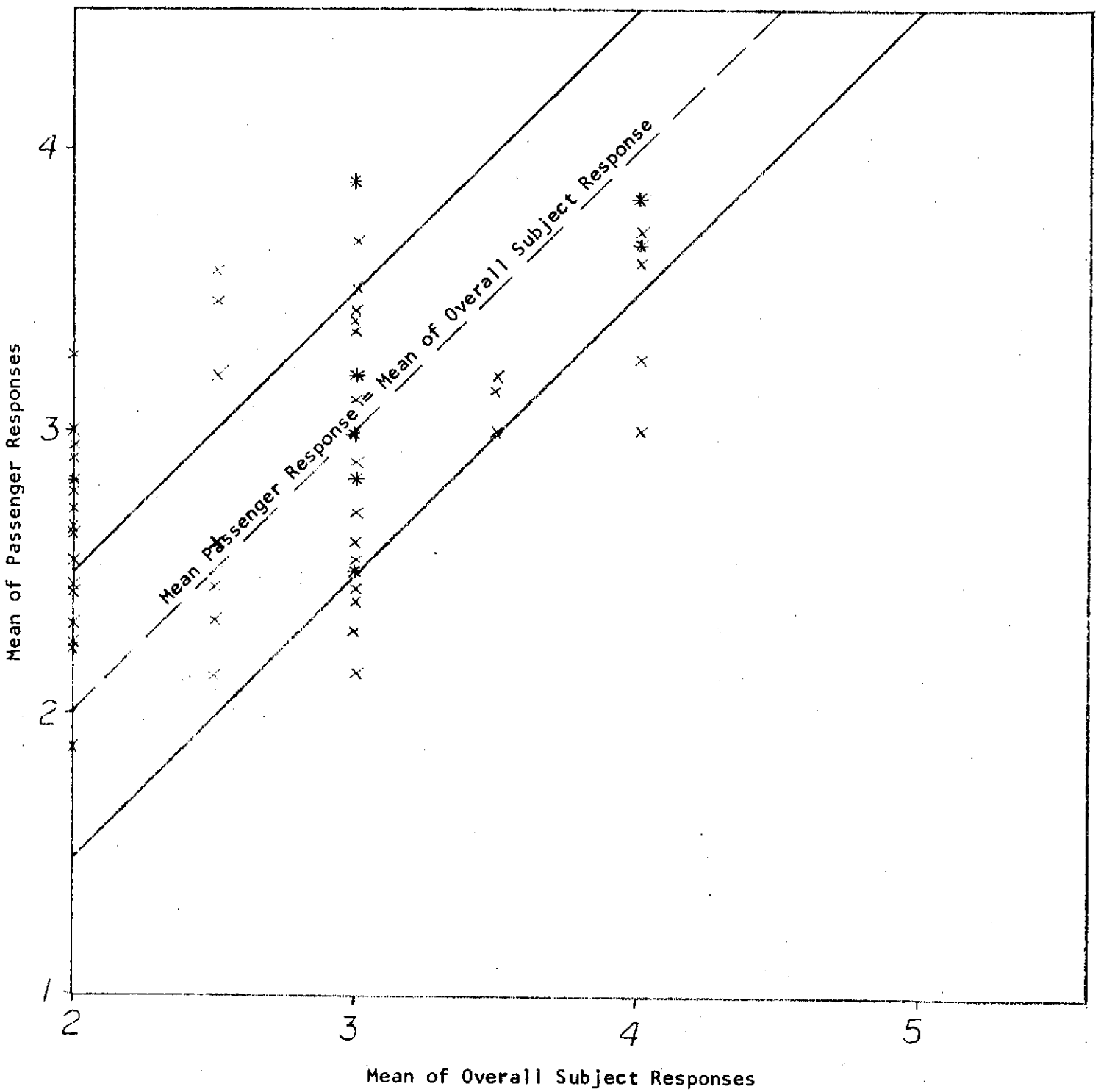
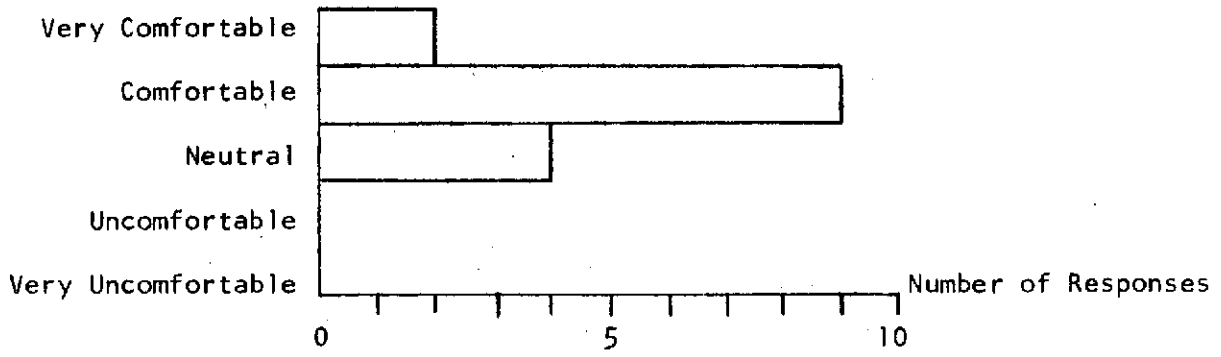
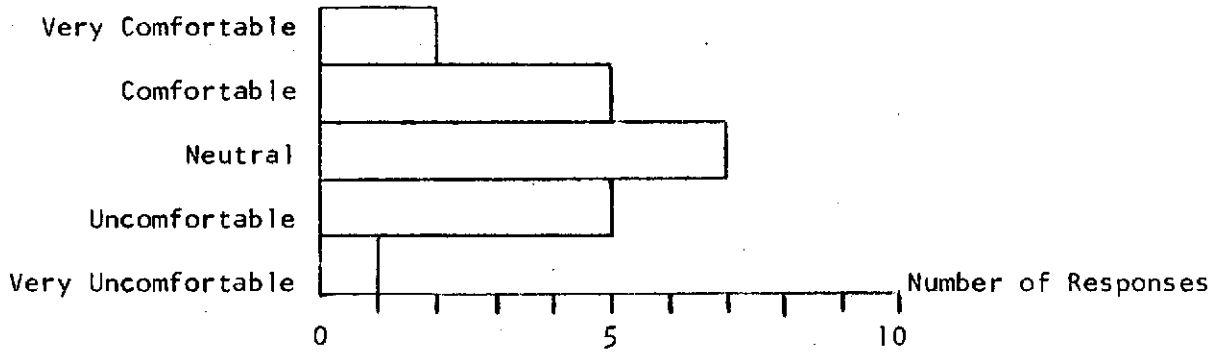


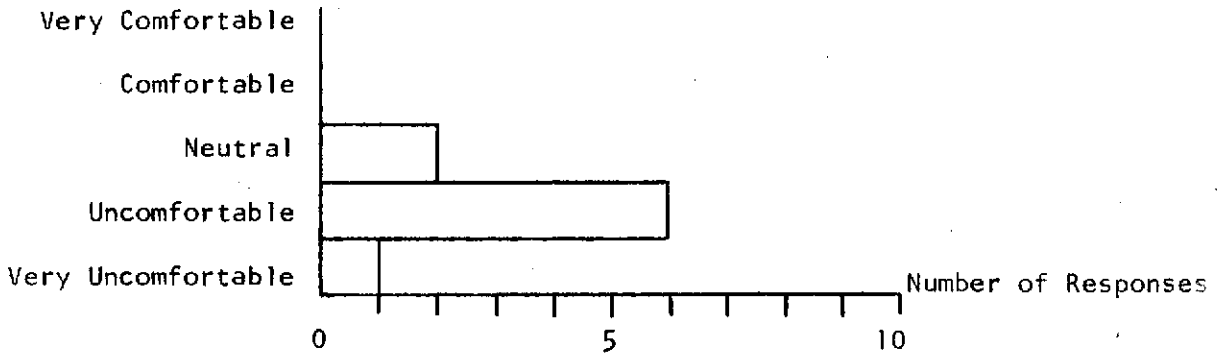
FIGURE 7. COMPARISON OF PASSENGER/SUBJECT RESPONSES



a. Mean Response = 2.1



b. Mean Response = 2.9



c. Mean Response = 3.9

FIGURE 8. TYPICAL PASSENGER RESPONSE HISTOGRAMS

One measure of the disagreement among passengers is the standard deviation of their responses (σ_P). In Table I, the percentage of cases for which the normalized error between passenger and subject responses (i.e., $\bar{C}_P - \bar{C}_S / \sigma_P$, where $\bar{C}_P$ and $\bar{C}_S$ are the means of the passenger and subject responses, respectively) is compared with a normal distribution of errors for the same normalized standard deviation. This table indicates that approximately 90% of the subjects' mean response is within one standard deviation of the passengers' response. In addition, the error distribution is considerably better (smaller) than that which would be obtained from a normal distribution.

Hence it can be said that passengers and subjects agree as to whether the flight is comfortable or not and the error in agreement is within a standard deviation of the passengers' response mean. On the other hand, passenger and subject ratings do not agree one to one, nor do they agree linearly with each other.

A third-order curve fit to the data of Figure 7 yields a nonlinear relationship for the passenger versus subject response,

$$P = 0.203S^3 - 1.74S^2 + 5.22S - 2.5 \qquad (1)$$

This is shown in Figure 9, where only 15% of the passenger responses disagreed by more than 0.5 from the transformed (see Equation 1) subject responses. Considering the small size of the subject group, it is felt that this represents reasonable agreement with passengers.

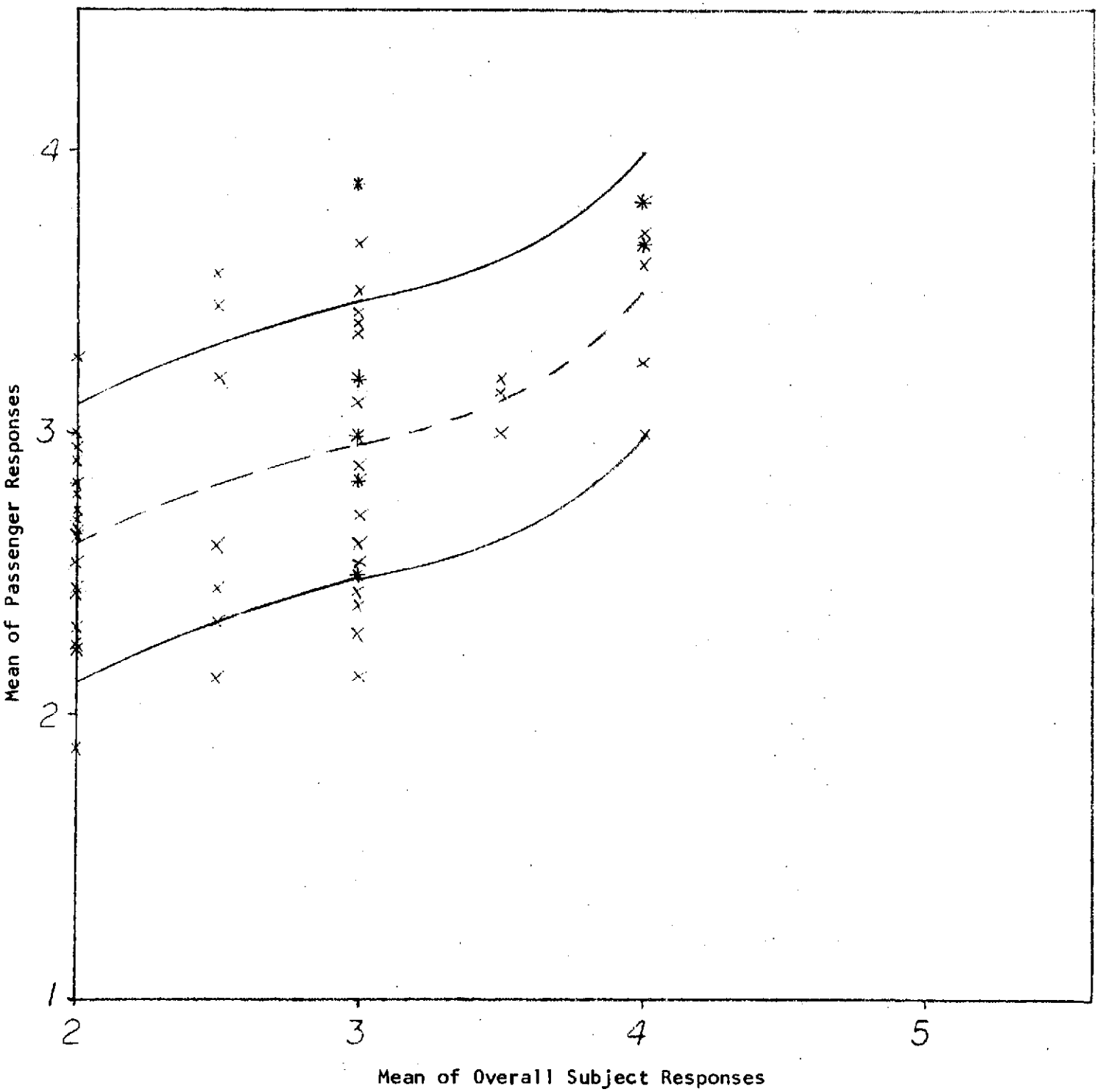


FIGURE 9. PASSENGER/SUBJECT TRANSFORMATION GIVEN BY $P = 0.203S^3 - 1.74S^2 + 5.22S - 2.5$

TABLE I

Normalized Error of Subject Responses

Error $\leq$	% of Cases	Cumulative Area Under Normal Distribution Curve (x 100)
$0.25\sigma_p$	28.6	19.7
$0.5\ \sigma_p$	44.4	38.3
$0.75\sigma_p$	68.3	54.7
$1.00\sigma_p$	87.3	68.3
$1.25\sigma_p$	93.6	78.9
$1.50\sigma_p$	100.0	86.6

Overall/Running Response

This section deals with the manner in which subjects integrate their experiences during the flight (running responses) to obtain their overall response for the entire flight. Various weighting functions were used to obtain weighted means of the running responses and these were compared with the overall responses.

Two types of weighting functions were tried: continuous and discrete. In the former, the weighting function [W(I)] is continuous and depends on the running response sequence number, I. In the latter, the entire flight is divided into four quarters and each quarter is assigned a weight.

Various continuous weighting functions (e.g., equal weight, $W(I) = 1.0$; linearly increasing weight, $W(I) = I$; etc.) were tried. An example of the physical significance of these can be seen from a linearly-increasing weighting function. Here the subject gives more importance to the environment at the end of the flight and less to that at the beginning in arriving at his overall reaction. Table 2 summarizes the results obtained. It can be seen that:

1. The mean of weighted means is equal to the mean of the overalls for $W(I) \sim I^{0.5}, I^{0.75}, I^{1.0}$.
2. The standard error between overall and the weighted mean is smallest for $W(I) \sim I^{0.5}, I^{0.75}, I^{1.0}$.
3. The error distribution is best for $W(I) \sim I^{0.5}$ and $I^{0.75}$.

Hence $W(I) \sim I^{0.75}$ or $I^{0.5}$ are favored and $I^{0.75}$ is chosen as the best weighting function. The $I^{0.75}$ weighting function is shown in Figure 10. This type of weighting implies that the passengers' overall reaction to the flight is a stronger function of the latter portion of the flight than the beginning.

TABLE 2

Comparison of Overall Response With Weighted Means Of Subjective Response (Continuously Weighted)

Type of Weighting Function W(I)		1.0	$I^{0.5}$	$I^{0.75}$	$I^{1.0}$	$I^{1.5}$	$I^{2.0}$
Percentage of cases for which the predicted overall response by weighting, C_w, differed over the actual overall response by:	>0.5	9	6	6	6	11	15
	>0.75	0	1	1	2	2	3
	>1.0	0	0	0	0	0	0
	>1.5	0	0	0	0	0	0
Mean of Weighted Means		2.8	2.9	2.9	2.7	3.0	3.0
Standard Error Between Overall and Weighted Mean		.3	.29	.29	.29	.31	.34

Number of flights: 89

Mean of Overall Response: 2.9

Definition: Weighted mean response $C_w = \frac{\sum_{I=1}^{n} C_I \, W(I)}{\sum_{I=1}^{n} W(I)}$

where I - response segment number

C - comfort index

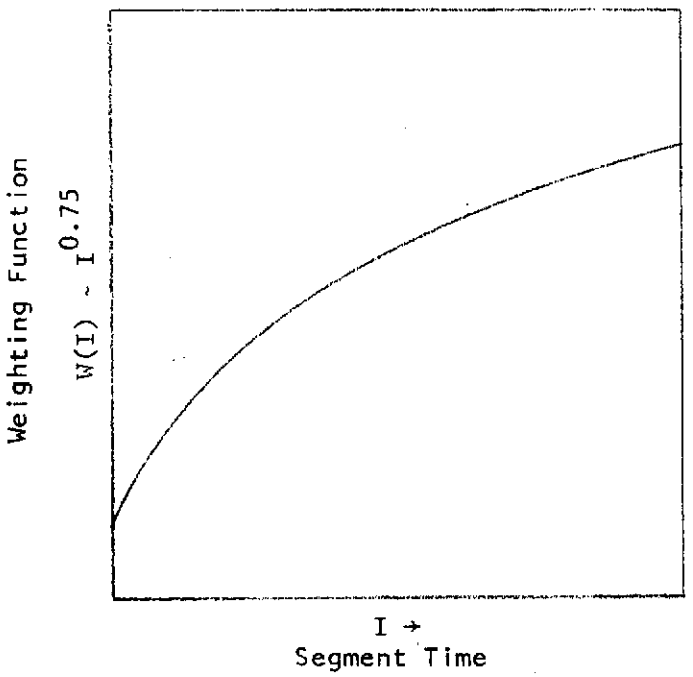


FIGURE 10. WEIGHTING FUNCTION--$I^{0.75}$

Next the discrete mode was considered. Here the subjective response (running) is divided into four groups (quarters) and each group assigned a weight.

Table 3 indicates those cases which have reasonable error distributions taken from all the permutations and combinations tried (these included weights of 0.25, 0.5, 0.75, and 1.0 for each quarter). In all, for 72 flights, the mean of the overall responses is 2.86.

TABLE 3

Comparison of Overall Response With Weighted Means of Subjective Response (Discrete Mode)

No.	Type of Weighting Function W	Mean of Weighted Means	σ_e - Standard Error Between Overall and Weighted Mean	% with error > 0.5	0.75	1.0	1.5
1	0.25/0.5/1/0.5	2.795	0.322	2.74	0	0	0
2	0.5/0.5/1/0.5	2.79	0.325	2.74	0	0	0
3	0.75/0.5/1/0.5	2.78	0.332	2.74	1.37	0	0
4	0.5/0.5/0.75/1	2.85	0.33	5.48	0	0	0
5	0.2/0.4/1/1	2.87	0.32	5.48	0	0	0

The best choice among these is with W ~ 0.25/0.5/1/0.5 with about 3% of cases disagreeing (error >0.5) but no error larger than 0.75. Further, the standard error is low (0.32) and the mean of weighted means (2.795) is close to that of the mean of overalls (2.86). The weighting function is shown in Figure 11.

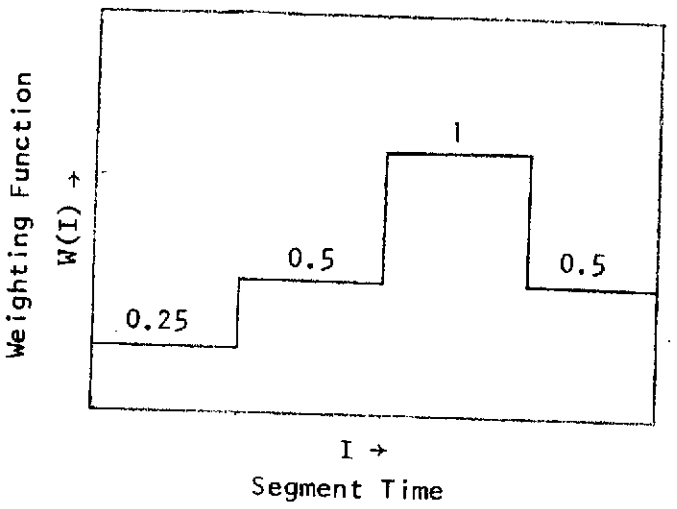


FIGURE 11. WEIGHTING FUNCTION--0.25/0.5/1/0.5

From discrete and continuous weighting it is seen that, with a suitable choice of weights, the percentage of cases with error >0.5 can be reduced to about 5%. This level of error is attributed to random error and hence cannot be eliminated.

It is felt that the continuous weight approach yields a more intuitively satisfying result, although the error is slightly greater. In all, the results indicate that a memory decay does occur (the beginning of a flight being less important than the end) and that the overall response of a subject can be predicted from his responses during a flight.

Conclusion

In conclusion it can be noted that:

a) Within acceptable limits, the crew/flight attendants do not appear to be able to predict passenger responses.

b) There exists a relationship between passenger and subject overall responses.

c) Finally, a strong relationship exists between a suitably weighted running and overall subjective response. The recommended weighting function is $W(I) \sim I^{0.75}$, indicating that the latter part of a flight is given more importance in a subject's overall comfort evaluation than the beginning of the flight.